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CATTLE FOR THE TROPICS *

WITH the exception of the llama and its cousin the alpaca of the high Andes and the turkey all the species of livestock in the Americas are introductions from across the seas. Some species and breeds have prospered in the New World, others have been greatly improved, and a number of new breeds have been developed in the Americas. Before the present war there was considerable exchange of improved stock between the twenty-one Republics of the Americas. Over the centuries and unawares, a vast trial-and-error experiment has been going on with these animal introductions, in a search to find that combination of climate, soil, and economic structure where the animals would thrive and serve man best. It is not surprising that there have been many failures. Breeds from northern climates have been introduced into the humid tropics, large breeds have been placed in regions of scanty vegetation, low-land breeds have been placed in the highlands and *vice versa*. Many species and breeds have been tried in almost every major livestock region of the Americas. Experience has taught us which fit best into given localities, and there is now discernible over the Americas a sort of stratification of types and breeds as they have found the areas of greatest usefulness to man.

It is in the tropical and sub-tropical regions of the Americas that a major dairy and beef cattle improvement problem exists, for the highly specialized European breeds do not thrive in hot climates. Before improvement of dairy and beef cattle is attempted there are two fundamental points to consider, firstly, that breeds differ in their ability to thrive in a warm or tropical environment and secondly that the improvement sought should be within the limitations of the environment to support the improved types. The first point emphasizes the necessity that improvement must be within or through the breeds of proven adaptability to a tropical environment. The second emphasizes the necessity of maintaining a balance between the degree of improvement sought and the level of the environment in which the breeds must produce and reproduce.

It is common knowledge that the present breeds of cattle found in tropical regions of the Americas ave not been highly selected or improved for

* Adapted from an article by A. O. Rhoad in *Agriculture in the Americas*, II, No. 12.

milk or meat production. They are, on the other hand, eminently suited by heredity to withstand the rigours of a tropical environment. From the point of view of the animal breeder the superior qualities of adaptability are as important in improving a breed as high milk production or desirable beef-type conformation.

The hitherto time-consuming, hit-and-miss method of determining adaptability of breeds to tropical environment is disappearing with the development of new scientific methods of determining the fitness of animals to survive in warm climates. At the Iberia Livestock Experiment Farm, Jeanerette, Louisiana, the United States Department of Agriculture is conducting certain physiological and other tests which measure the degree of heat tolerance of cattle. What previously took several generations of cattle to determine, may now be accomplished through these tests in a few weeks. From these tests it has been determined that as the amount of Brahman (zebu) breeding is increased in a strain of cattle, the heat tolerance increases. Cattle with a high proportion of Brahman blood do not suffer because of high atmospheric temperatures. Because such cattle can stand the heat they will graze longer during the day, will keep in better flesh, and will not decrease in milk production because of high atmospheric temperatures. Experiments have shown that breeds or individuals within a breed, that cannot remain comfortable in a tropical environment become distressed, exhausted, and develop a febrile condition in their bodies which is harmful to reproductive functions and deleterious to normal growth and production and, if long continued, causes a degeneration of the stock.

Experiments have also shown that coat colour is important. Cattle with the lighter coat colours, as the white of the Brahman or the fawn of the Jersey, throw off a much larger proportion of the intense solar heat than cattle with deep coloured or black coats. Short hair and pigmented skin are also important. Short hair permits greater freedom of body heat elimination and offers less protection to cattle ticks. A deeply pigmented skin underneath the hair coat impedes the penetration of strong solar rays which cause skin burn in animals with non-pigmented skins. Breeds native to the tropics, as the Brahman, or such "native" breeds as the Criollo that have, through the centuries, become acclimatised to warm climates, possess short hair coats, have pigmented skins, usually are gray or cream-coloured, and—most important — are physiologically adjusted to warm climates. All these add up to demonstrated heat tolerance and adaptability to a tropical environment.

The established native breeds and those carrying Brahman (zebu) blood are genetically adjusted to the warm climates, but many are low producers of the products for which they are kept. The problem of the animal breeder is to develop in these breeds greater specialization in meat or milk production without materially reducing their superior adaptability. The amount of heat tolerance to retain or to breed into cattle depends on the severity of the climatic conditions. In the sub-tropical Gulf coast region of the United States one-fourth Brahman and three-fourths European breeding is sufficient. As the climate approaches true tropical conditions a greater proportion of Brahman breeding, or native breeding carrying equivalent heat tolerance, would be necessary to insure satisfactory adjustment to the tropical environment. To have animals genetically adjusted to the tropical environment is a primary prerequisite to any successful cattle-breeding programme directed towards increasing production.

With meat animals the problem is not so difficult as with dairy animals, for within certain of the tropical breeds the variation in type is sufficiently wide to permit selection towards the ideal beef type without introduction, through crossbreeding, of beef blood from exotic breeds. That specialized beef type animals, approaching the ideal, can be developed within pure tropical breeds is demonstrated in the improvement made in the zebu in Brazil and in the United States. The Caracú of Brazil and the Blanco-Orejinegro of Colombia are examples of similar improvement through selection within the pure native breeds.

Crossbreeding the native or the Brahman with specialized European beef-type breeds is carried on in many tropical parts of the Americas where the tropical breeds show only limited specialization as beef animals. In other words, these animals are inefficient producers because their inherent capacity to produce is below what the environment can support; specialized exotic breeds are imported to increase the potential level of production in order that the resulting crossbred may be a more efficient animal. In the Gulf coast region of the United States, cattle are bred-up so close to the pure-bred European type that Brahman cattle are used to incorporate heat tolerance into the former. Here the environmental level and the potential level of production are in reverse relationship to the above, for along the Gulf coast inherent capacity to produce is above what the environment can support; consequently growth, production, and reproduction suffer. Exotic tropical breeds are imported to increase heat tolerance in order that the resulting crossbred may be more in harmony with its environment and, therefore, a more efficient animal. Whether the crossbreeding is carried on under the severe environmental conditions of the tropics or under the milder conditions of the Gulf coast, a proper balance between heat tolerance and beef type must be maintained for the best results. Once the proper adjustment between heat tolerance and beef type is obtained in the crossbreds,

progress towards fixing new strains through the systematic application of known genetic principles may be made. In this manner the Santa Gertrudis breed of beef cattle of southeast Texas was evolved.

That more extensive crossbreeding with beef cattle has not been carried on in tropical regions is partly explained by the fact that the beef breeds are also the chief source of work animals. This is an important consideration to the farmer and breeder, for much of the heavy farm work and transportation is done by work oxen. Because of their heat tolerance, the tropical breeds have proved eminently suited to work in the yoke. Crossbred oxen with less heat tolerance have frequently proved undesirable because of their inability to work and remain in reasonably good flesh in a tropical environment.

While the principle of maintaining a balance between the animal's capacity to produce and the environment's capacity to support is equally applicable to dairy cattle, the solution is more difficult because the level of milk production of native tropcial cattle is generally low. Development of specialized dairy animals within the native tropical breeds of the Americas is, therefore not likely to occur. Working with a group of animals whose proved production under the best of feeding and management does not exceed 2,000 pounds, it is quite impossible, genetically, to develop a tropical dairy breed with an average milk production of 5,000 pounds. If the group does not carry the genes for an average production of more than 2,000 pounds, there are no genetic means of increasing production without incorporating genes for high production through crossbreeding with an exotic breed possessing the necessary genes. This fact has been generally recognized throughout tropical America. As a result, recourse to cross breeding to increase milk production is more generally carried on than cross breeding to increase beef production.

With dairy cattle, man frequently lessens the effects of adverse tropical conditions by adjusting the environment through better feeding, especially during periods of drought, and by furnishing some shelter from intense solar radiation. Air-conditioned dairy barns have come into use in some tropical countries. Where the environment has thus been adjusted, a higher proportion of exotic blood from breeds possessing the genes for a high level of milk production may be incorporated in the herd. Crossbreeding the native or the Brahman with the high producing exotic dairy breeds has been carried on for many years in various parts of tropical America. Although frequently the crossbreeding has not been done in a systematic way, there are available at the present time large numbers of crossbred dairy animals. Through the process of several generations of inter-se crossbred matings and the elimination through natural causes of the less adaptable progeny, there are within these large population many individuals in which the superior qualities of both parental stocks are harmoniously combined. Although they are quite heterozygous and therefore uncertain in their transmitting abilities, they are good basic stock from which new types and breeds may be evolved through the application of known genetic principles.

Where the pure tropical breeds have demonstrated efficient production and where desirable crossbred types are available in considerable numbers, the process of improving or perfecting them for meat or milk production requires only the systematic application of well-established breeding methods that are followed in many of the modern specialized breeds. Where, on the other hand, tropical breeds of demonstrated productive efficiency are lacking and where desirable crossbred types are not available, an important breeding problem exists in determining what foreign specialized breeds should be used in making the original crosses and to what extent the crossbreeding should be carried.

The solution of this important problem is dependent upon a study of the conditions of the environment in which the animals are to be maintained and also of the degree of adaptability of the foundation stock and of the foreign breed to a tropical environment. The initial genetic problem is to develop a type of animal whose level of production and adaptability are in harmony with the level of the environment.

REVIEW

Entomologia Agricola del Peru

By Johannes E. Wille. Estacion Experimental Agricola de la Molina, Peru. 1943 vii + 468 pp., 213 figs., $5 U. S.

This is a practical book on the agricultural entomology of Peru, written for entomologists, agriculturists and students of agriculture. A preface outlines the history of economic entomology in Peru, and an introductory chapter discusses the importance of insects and the climatic and ecological conditions which influence outbreaks of pests in that country. There are chapters on the insects attacking the following crops:—cotton, sugar cane, rice, wheat, maize, coffee, cacao, tea, tobacco, citrus, olives and other fruits, vegetables and other cultivated plants. There is a chapter on the insects which attack stored produce and one on the various methods of insect pest control. The book concludes with a bibliography, a glossary and an index.

Dr. Wille is to be congratulated on his book which will undoubtedly be of use in Peru, and brings the pest control problems in agriculture in this part of South America to the notice of entomologists in other parts of the world.

E. McC.C.

OBSERVATIONS ON SUGAR CANE CULTIVATION IN VENEZUELA

BY

ALAN PICKLES

(*Entomologist, Department of Agriculture, Trinidad and Tobago*)

The following notes were prepared during a visit to Venezuela in November, 1943, when, at the request of the Venezuelan Government, the writer visited many of the sugar-growing districts in connection with a scheme of sugar cane investigations which has recently been inaugurated in that country.

The Sugar Industry

Production of crystallised sugar is a relatively minor function of the Venezuelan sugar industry and the most important product is "Papelon", a crude brown sugar prepared by concentrating cane juice until it solidifies. The domestic demand for sugar is increasing and, in order to satisfy the local market, some sugar is imported. No statistics, however, could be found of the quantity of sugar imported. Papelon, on the other hand is exported to destinations outside the country; the amount exported fluctuates greatly from year to year. Thus, in 1920, the amount of papelon exported amounted to 5,500 tons, to only 22 tons in 1935 and to 340 tons in 1937.

The total production of sugar cane products in 1937, according to the Annuario Estadistico de Venezuela for 1940, was as follows:—

Sugar	....	21,000 tons;
Papelon	....	134,200 tons;
Rum	....	1,597,500 gallons;
Alcohol	....	69,500 gallons.

The quantity of sugar products exported is consequently a very small proportion of the total production and, for various reasons it is unlikely that Venezuelan sugar could be put on the export market on a competitive basis, at any rate for many years to come.

Environmental Features of Sugar Areas

The areas devoted to commercial production of sugar cane in Venezuela are discontinuous and are separated from each other by mountain ranges and other natural barriers. Sugar cane is produced at varying elevations above sea level; the cultivations in the Caracas Valley, for instance are about 3,000 feet above the sea; in the Aragua Valley, cane is produced at elevations of approximately 1,000 feet, while in the State of Zulia, the principal cultivations are situated very little above sea level. The soil of the sugar cane estates is nearly always a river alluvium and about half of the estate cultivations are situated in narrow river valleys. Most of the soils are of reasonably high fertility, often extremely fertile but, in many cases, the soil is shallow. In the states of Aragua and Carabobo the sugar soils are derived from detritus from Lake Maracay and are shallow, highly calcareous layers overlying deep beds of fresh water shells.

Rainfall in these areas is low and the practice of irrigation is general in sugar cultivations. The amount of annual precipitation may be illustrated by the following figures from stations in certain of the sugar-producing regions for 1938 (a relatively wet year) and 1939 (a dry year):

LOCALITY	TOTAL RAINFALL (INCHES)	
	1938	1939
Caracas	48.3	19.8
Barquisimeto ...	33.4	22.2
Maracaibo	27.4	12.8
Maracay	46.9	28.3
Valencia	45.9	40.1

Wet and dry seasons are well marked, with about two-thirds of the total annual rainfall occurring in the months July to December. Two or three consecutive rainless months are not uncommon in the dry season and in 1940 at Maracaibo no rain at all fell during the months January to September inclusive.

Cultivation Practice

With few exceptions sugar cane is planted and reaped continuosuly throughout the year, there being no recognised crop season. In preparing a field for re-planting, the trash, stubble and dead cane are first burned. The land is then ploughed to a depth of about six inches. Some pen manure may be applied during this preliminary cultivation, but the use of pen manure is somewhat exceptional. The cane is planted flat in the furrows, using cane tops which are placed end to end continuously across the field or even over-lapping slightly; the sets are lightly moulded over with soil and the field is then irrigated immediately. Irrigation is repeated at intervals of about ten days throughout the growing period and, on each occasion, the water is allowed to flow for two or three hours.

Sprouting of the cane is accompanied by copious growth of weeds, and soon after germination of the canes, the weeds and much of the soil surrounding the young plants are drawn back into the ridges by hand hoes. When the canes are 2½ months old, the ridges are half-broken by hand and the soil is used to mould up the growing plants. This operation reduces the ridges sufficiently to enable a 5-tooth, horse-drawn cultivator

to pass through the field, breaking up the soil of the inter-rows. At 4½ months after planting the remainder of the original ridges is moulded around the stools and this completes the work of cultivation proper. Irrigation continues at intervals of ten days, however, up to the time of reaping.

The use of fertilisers is now coming into vogue on Venezuelan sugar estates, but practice is somewhat haphazard; as a rule, the field is burned, cultivated and re-planted immediately the plant-cane crop has been harvested. The fields are never divided into beds and no drainage is practised except that a bottom drain is used to collect surplus irrigation water.

Varieties Grown

The number of cane varieties utilised in Venezuela is very limited and the greater part of the sugar-producing lands is planted in BH 10/12. The only other variety grown to an appreciable extent is FC 916: Crystallina, POJ 2878 and various other varieties are sometimes grown to a very limited extent.

An urgent need of the industry is a variety resistant to mosaic disease; drought resistant varieties are also desirable for those areas in which irrigation cannot conveniently be practised.

Yield

In most cases, cane is not weighed when it is removed from the fields and the yields of cane obtained can only be roughly estimated. Most planters claim an average yield of about forty tons per acre, though officers of the Ministry of Agriculture state that the average in reality hardly exceeds thirty tons per acre.

Chemical control in the factories is exceptional and, in consequence, there is little information as to the yield of sugar. It appears, however, that juices are generally poor and that about fourteen tons of cane are required to produce a ton of sugar.

Having regard to the fact that a large proportion of cane is cultivated in rich, porous, vega soil, that irrigation is general and that only plant cane is produced, these yields are surprisingly low and indicate that methods of cultivation, and especially of irrigation, could be improved considerably.

Pests and Diseases

Sugar cane production in Venezuela is seriously handicapped by the presence of diseases and pests. Of these, mosaic disease, particularly prevalent on BH 10/12, is much the most serious and is probably the greatest single factor restricting the production of ratoon canes. Fields in which 90 per cent. of the stools are affected are of common occurrence. So serious is the incidence of mosaic disease at the present time that it is doubtful if any estate operations could appreciably reduce it. Many routine practices, however, have facilitated the spread of mosaic in the past, especially the planting of unselected "seed", the custom of cutting plants from the worst fields and the practice of inter-planting corn and cane. The only possibility of alleviating the situation appears to lie in introducing resistant varieties and using them to replace BH 10/12 as completely and as rapidly as possible.

Damage by *Diatraea* appears also to be a serious source of loss in Venezuelan sugar plantations; the species concerned and the extent of the damage probably vary from place to place, but no survey has been made to estimate the severity of the injury. Casual examination of recently reaped cane, however, indicates that at least 15 per cent. of the joints are bored in most localities; this compares with 2-3 per cent. joint infestation in Trinidad. In certain isolated areas, however, *Diatraea* incidence is low and it is stated that, in at least one of these, parasites of the larvae are abundant and may, at least in part, account for the scarcity of the pest.

Attack by sugar cane froghoppers has been a matter of concern to many sugar planters in Venezuela for the last thirty years. It is possible that several species are concerned, although specimens examined by the writer from states as widely separated as Carabobo and Zulia were all of one species, *Tomaspis bodkini* Williams. This species is closely related to the Trinidad sugar cane froghopper and might easily be mistaken for it. It is difficult without seeing an attack actively in progress, to compare the severity of the froghopper problem in Venezuela with that in Trinidad. On one estate visited, where the cane cultivation extended over 2,600 acres, 185 acres or 7.1 per cent. were stated to have been seriously attacked by froghopper in 1941, a year of record severity of attack and the loss of crop in the fields affected was estimated at 75 per cent. On the other hand, fields visited by the writer, when recovery from a reputedly serious attack had commenced, did not appear to have been so severely checked in growth as is often the case in Trinidad.

It is of interest to record that, on this estate (Central Tacarigua, state of Carabobo) nymphs of a Pentatomid bug were observed to attack an adult froghopper. There is a possibility that this insect controls froghopper to an appreciable extent and the matter is to be actively investigated by the officers of the Ministry of Agriculture; if this should prove to be the case, and if the predator is found, on investigation, to be harmless to plants throughout its life-history, arrangements will be made to introduce it into Trinidad.

An unidentified Jassid has been observed to injure sugar cane in the Caracas Valley and the writer was fortunate enough to see an active infestation in progress. The symptoms of attack resemble those of froghopper blight, except that the "blight streaks" are much smaller in extent and the cumulative effect is much less serious;

indeed, although the fields affected presented a somewhat scorched appearance, it is doubtful if the yield will be affected appreciably.

In addition to *Diatraea*, several other insects, especially beetles, bore into cane stalks; the identity and primarily injurious nature of these insects still remain to be established.

The large Moth Borer, *Castnia licus*, is known to occur in parts of Eastern Venezuela in bananas and Heliconia, but this insect does not appear to be a familiar pest of sugar cane.

Possible Lines of Improvement of Sugar Cultivation

From the preceding account of methods of cultivation practised in Venezuelan sugar estates it will be apparent that current practice, even on the larger estates, is based on traditional methods and that many of the methods demand scientific investigation to determine if they are the best which could be devised for local conditions.

Field experiments with sugar cane have been recently commenced under the auspices of the Ministry of Agriculture and the original programme is likely to be greatly expanded in the near future with the object, not so much of increasing the production of sugar and papelon, as of reducing the costs of production.

That existing methods are not all that could be desired is suggested by the relatively low yields of cane and sugar, having regard to the conditions in which cane is produced. In addition, a very large quantity of dead cane is left in the fields at the time of reaping; such cane is seldom found to be killed by pests or diseases and it seems most probable that the management of irrigation is faulty. There can be no doubt that, in the absence of even shallow drains, parts of an irrigated field remain water-logged for long periods and much of the benefit of irrigation is thereby lost. It is of interest to note that, at Central Tacarigua, where irrigation is not possible, the yields of cane are well up to average for the district, although the rainfall is no higher and the soil is of similar nature and fertility to that of other sugar estates in the same state.

In the absence of records of yield of individual fields, it is difficult to state whether the prevailing practice of continuous reaping and planting is economically sound or not. Those few estates which reap during a specified season of the year certainly appear to obtain juice of better quality than the remainder.

The most pressing needs of the industry appear to be the following:

(1) The institution of a proper system of field accounts;
(2) Revision of irrigation practice;
(3) Control of mosaic disease;
(4) Scientific use of fertilisers and manures;
(5) Production of cheap and remunerative ratoon crops.

It appears likely that all these problems will receive attention as soon as results are obtained from the Ministry's experimental programme.

CORRESPONDENCE

DEPARTMENT OF AGRICULTURE
CYPRUS,
NICOSIA,
27th November, 1943

TO THE EDITOR, *Tropical Agriculture*,

DEAR SIR,

I have just been reading the very interesting article by Mr. O. T. Faulkner and Professor C. Y. Shephard on "Mixed Farming" published in the July number of *Tropical Agriculture*. It occurred to me that one of our local practices in Cyprus might be of some assistance in solving one of the problems they visualise—that of the disposal of milk if peasants are to keep a larger number of milking animals.

In Cyprus the milk animal is the sheep (or goat) which is grazed in herds of about 100 and cared for by professional shepherds. In many cases these herds are composed of animals belonging to several owners who pay the shepherd for looking after the animals at so much per head. During the milking season the individual owners do not each milk their own sheep but the herd is milked as a whole and each owner gets all the milk from the whole herd for a number of days proportional to the number of sheep which he owns in the flock.

By this method every owner is assured of getting at intervals a large quantity of milk which he will normally convert to a kind of soft cheese called "halloumi". This forms both a staple article in the diet of the peasant and a readily saleable article which is not of such a perishable nature as fresh milk.

As can be realised this system has a number of advantages in that the peasant who only owns a few sheep deals at intervals with a satisfactorily large volume of milk which enables him economically to turn it into a non-perishable commodity which he can then deal with as he likes—consume it himself or sell it for cash. There is always a good local market for "halloumi".

I do not of course suggest that exactly the same system could be established with cows among West Indian peasants, but it occurred to me that the principle, whereby the milk from a large number of animals was pooled and the whole of one milking given in turn to the owners of the animals to convert into non-perishable or semi-perishable goods, might be adapted in some way to West Indian conditions. The system is well adapted to the traditionally independent outlook of the peasant in that the subsequent disposal of his produce is entirely at his own discretion and it is rather remarkable that in Cyprus, where the average farmer has all the conservatism and non-cooperative attitude of the typical peasant, this essentially co-operative system should be more or less traditional.

Yours faithfully,

L. J. S. LITTLEJOHN,
Botanist and Plant Pathologist,
(Postgraduate 1937-38)

GUAVA YIELDS IN BRITISH GUIANA

BY

C. H. B. WILLIAMS AND P. A. CHAN CHOONG
(*Department of Agriculture, British Guiana*)

The guava (*Psidium Guajava L.*) is a small tree of the Myrtle family, native of tropical America, which thrives throughout the Caribbean. Its fruit is well known as a source of jelly and jams and some thick-fleshed varieties are greatly appreciated as fresh fruit. More recently Goldberg and Levy (1941) and Boyes and de Villiers have called attention to the high value of guava as a source of vitamin C, and Campos (1943) has found it a good source of thiamine and riboflavin. Yield data are, however, rare in the literature, and the records here presented may be of general interest.

While two or three trees are to be found among the small fruit orchards which are attached to many dwellings, no fields of guava have been established in British Guiana and no well-defined varieties are known or established. By far the greater proportion of the crop is collected from spontaneous growth on abandoned areas and the output is not of sufficient importance in the economy of the Colony to warrant detailed agricultural research. Some information has, however, been collected in the past few years and it is hoped that this note may be of service to those contemplating the establishment of solid plantings.

In September 1937 fruit were collected from six trees in the County of Essequibo and seed germinated shortly after at the Sugar Experiment Station. On August 22, 1938, 16 seedlings from each parent tree were put in the field, at the Rice Experiment Station, and the groups labelled, with regard to the colour of the original fruit and the point of collection :

1. Affiance Red
2. Essequibo White
3. Anna Regina Red
4. Sue, Supenaam Red
5. Sue, Supenaam White
6. Suddie Pear White

The trees were planted, 15 feet apart, in single rows on beds 24 feet wide from centre to centre of the dividing drains. They have not been manured and the cultural operations have been limited to an occasional cutlassing of the weeds and some pruning to give the trees a proper shape. Attempts have been made to establish a cover of *Indigofera endecaphylla* and this is spreading slowly.

It was decided to record the yields of individual trees with a view to estimating roughly, (*a*) the variation which may be expected if an orchard is established from seed of a given tree and (*b*) the yields which may be expected from (i) such an orchard of mixed seedlings and (ii) an orchard consisting of high yielders only.

Pests and Diseases

The only serious trouble experienced with pests or diseases has been damage to large fleshy types, suitable as dessert fruit, by gnawing of the flesh of mature guavas by an adult wasp, identified by the Entomological Division as *Synoeca surinama*, L.

Cropping

Bearing commenced about two years after transplanting and five crops have been harvested, *viz* :

Autumn 1940 :	27. VII to 2. XI.
Autumn 1941 :	28. IX to 8. XI.
Spring 1942 :	4. IV to 2. V.
Autumn 1942 :	25. VIII to 12. X.
Spring 1943 :	18. III to 24. V.

The rainfall from January to May, 1941, was was only 52 per cent. of the normal and no spring crop was recorded. The average duration of picking for each crop was about eight weeks.

Yields

Table I shows the actual yields for each tree together with the average dimensions of each block of trees, and in Table II the potential yields per acre of various groups are presented.

No attempt was made to randomise the types to permit of a statistical analysis of the results, but close observation and the yield figures suggest that the soil of the area was reasonably uniform except for the site of trees 1-5 of Sue, Supenaam White, which appear to have fallen on a portion of more fertile land that had been used for a vegetable garden in the past.

Conclusions

The results indicate that :

1. Considerable variation in yield and in size of fruit, from tree to tree, may be expected even if a solid planting is established with seed from one tree, but the average yield of trees from one parent may more than double that of trees from another parent.

2. It would not be unreasonable to expect in two- eight-week crops and without manuring, a yield of 10,000 lb. per acre per annum from mature trees from a good parent, *i.e.* a remunerative output even at a price of one cent per lb.

TABLE I

Yields of Guava Per Tree Per Crop Based on Records of the First to the Fifth Crop

Tree	Affiance Red 1		Essequibo White 2		Anna Regina Red 3		Sue, Supenaam Red 4		Sue, Supenaam White 5		Suddie Pear White 6	
	Yield lb.	No. of fruit per lb.	Yield lb.	No. of fruit per lb.	Yield lb.	No. of fruit per lb.	Yield lb.	No. of fruit per lb.	Yield lb.	No. of fruit per lb.	Yield lb.	No. of fruit per lb.
1 ...	22.5	15.8	21.1	16.3	35.2	16.3	8.3	23.8	41.5	5.3	10.9	15.3
2 ...	26.8	16.4	19.0	14.5	26.7	16.8	11.3	18.8	39.5	6.8	5.9	10.3
3 ...	20.1	16.9	30.2	10.4	38.6	14.5	9.2	20.8	39.7	6.3	4.8	9.8
4 ...	20.3	16.5	34.1	12.1	20.9	15.7	15.8	18.9	39.3	6.9	8.0	9.1
5 ...	22.8	13.0	31.2	13.5	22.5	15.0	8.1	23.2	46.4	7.9	6.8	9.3
6 ...	20.8	15.2	26.8	11.5	19.5	14.7	7.9	20.4	27.5	5.4	4.2	9.6
7 ...	17.7	18.7	22.8	13.6	24.1	14.6	10.0	23.2	15.3	9.2	3.2	9.7
8 ...	13.4	16.6	17.4	11.3	29.4	15.8	9.6	18.4	14.7	12.9	3.6	8.3
9 ...	17.0	17.8	19.8	13.4	28.6	16.1	6.4	26.8	16.4	12.7	2.0	7.2
10 ...	9.6	16.2	4.7	15.0	31.1	15.2	10.8	20.2	16.2	9.0	4.2	9.1
11 ...	21.6	15.7	16.2	13.4	33.3	12.6	15.6	20.5	16.1	8.7	6.6	7.2
12 ...	21.2	13.5	14.7	11.8	23.3	15.8	14.2	18.0	13.3	8.3	16.1	7.5
13 ...	26.9	14.7	16.6	13.2	24.3	13.9	11.9	19.7	8.0	7.6	8.7	6.7
14 ...	30.8	17.4	25.0	14.1	24.6	13.1	13.4	20.5	7.5	7.1	6.8	7.3
15 ...	18.9	19.9	22.4	16.3	18.9	13.4	12.2	21.6	8.5	12.2	11.3	8.2
16 ...	23.0	15.7	19.3	11.9	35.9	12.5	9.7	17.0	7.1	9.6	10.6	8.6
Mean ...	20.8	16.2	21.3	13.1	27.3	14.7	10.9	20.4	22.3	7.7	7.1	9.0
Present Mean Tree Height, ft.	8.5		9.9		10.0		9.4		12.1		10.8	
Present Mean Tree Diameter, ft. ...	10.2		11.9		1.6		9.7		13.5		9.9	

TABLE II

Calculated Guava Yields in Lbs. Per Acre Per Annum (Assuming 2 Crops and 222 Trees Per Acre)

Category	Affiance Red lbs. per acre	Essequibo White lbs. per acre	Anna Regina Red lbs. per acre	Sue, Supenaam Red lbs. per acre	Sue, Supenaam White lbs. per acre	Suddie Pear White lbs. per acre
2 Best Trees ...	12,809	14,497	16,539	6,971	19,514	6,083
2 Worst Trees ...	5,106	4,307	8,525	3,175	3,241	1,154
All Trees ...	9,235	9,457	12,121	4,840	9,901	3,152

3. In view of the fact that the yields of the best trees are some 56 per cent. above the average for all trees, and 200 per cent. above that of the worst, blocks of clones from the highest yielders should be established by vegetative propagation with a view to determining whether a pure stand of high yielders can be secured in this way.

4. Under local conditions trees should be spaced 14 × 14 ft.

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SWEET POTATO VARIETY EXPERIMENTS AT THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, 1927-43

BY

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THIS paper describes a series of field trials conducted at the College Farm on local and imported varieties of the sweet potato (*Ipomoea batatas* L.) which is an important food crop in the West Indies. The farm is situated on relatively flat lands, at the foot of the hills of the Northern Range of Trinidad. The soil type is a slightly acidic sandy to gravelly free draining loam. The main crop of sweet potatoes is grown from September to March, a period which is typified by a wet growing season followed by dry sunny weather for harvest. Crops planted between May and September produce numerous vines but often give disappointing yields of tubers. Vine cuttings are used for planting the main crop in September. These cuttings are obtained from small unsaleable tubers planted 12 ins. apart on irrigated nursery beds, after harvesting the main crop in March. Vines produced by these same tubers are used in July to extend the nursery and by September one acre of fully established nursery usually provides sufficient cuttings to plant 10 to 25 acres.

The farm crop is grown on land which has been ploughed and disc harrowed. Pen manure is spread evenly at 10 to 12 tons per acre and the soil is immediately thrown up into ridges 3 ft. apart by light digger ploughs. Finally the ridges are shaped, large clods pulverised, and noxious weeds removed by hand with the West Indian banking hoe, the completed ridge being about 18 inches high. Cuttings about 12 to 18 inches long which are taken from the apices of vines are planted one foot apart on the crest of the ridge. The cutting is inserted 9 inches deep at an angle of about 45° into an opening made by a cutlass. The crop is generally given two weedings, the rooting of vines at the nodes being discouraged. After five to six months of growth the tubers are harvested. Vines are first stripped off the banks by hand and the tubers are then ploughed out with the "Sweet Potato" plough, which is designed with a bi-winged share and corresponding left and right slatted mould-boards. The lifted tubers are gathered by hand, adhering soil, roots and stems being removed before storing in sacks in a well ventilated room.

From 1927 to 1943, field trials were conducted during the September to March season of each year. This work was carried out by a number of postgraduate and diploma students in connection with their courses in agriculture at the Imperial College of Tropical Agriculture. All the main experiments were properly designed and replicated on modern scientific principles and the results statistically analysed. The more important lines of investigations included the performance of varieties in regard to (i) yield of tubers and vines, (ii) quality, (iii) storage, (iv) susceptibility to the stem and root borer *Megastes grandalis* Guen.

Some of the trials were disappointing because they failed to show conclusive differences between the treatments or varieties under comparison. The experimental error was unavoidably high owing to seasonal vagaries, high soil fertility variations, the different maturing dates of varieties, and insect pests. Seasonal differences exerted the greatest effect on the yield of vines and tubers, varieties responding differently to these. In general, however dry conditions are unfavourable to all varieties. The crop is most productive when grown in a season having 25 to 30 inches of rain evenly distributed over the period of vegetative growth, followed by a dry month immediately before harvesting. The average yields of varieties during the 16 years of experimentation were low, and under conditions obtaining at the College Farm the sweet potato has not been a paying cash crop. In some other districts in Trinidad, however, and in other parts of the Caribbean area higher average yields are apparently obtained and there is reason to believe that the crop is more remunerative. In fact, varieties which were found unsuccessful in our trials are reported to have given satisfactory results under different environmental conditions. Similarly, our best varieties may prove unsuccessful in other localities. The results here described must not therefore be regarded as having universal application. Thus, while some of the tentative conclusions given in this paper relating to the general principles of cultivation, propagation, storage and potential pests may be of fairly widespread application in the West Indies any detailed data and results in the way of relative variety yields, planting dates, precise manurial requirements, must of necessity be regarded as of more local and limited significance.

Results of Variety Trials

(i) YIELD OF VARIETIES

During the decade 1927-36, twenty-two varieties were tested (*see* Appendix) by various post-graduate students: Musk and Dias (8), Dalgarno (3), Chambers (2), Halcrow (4), Hindson (5) and Inniss (7). The most outstanding yielders up to 1933 were the "local" varieties Black Rock, Jackson and Red Nut. In 1936, however, six new varieties were included in the trials and as a result Black Rock and V52

(a hybrid from St. Vincent) were selected as the most promising varieties. Table I shows the average yield of the outstanding "good" varieties for the period 1927-36.

Table I

Average Yield of Good Varieties of Sweet Potato for 1927-36

Variety	Av. yield of tubers in tons per acre	No. of years tested
V52 ...	6.97	1
Black Rock	4.06	4
Jackson .	2.40	4
Red Nut ...	3.90	3

Significant difference at 5 per cent. point=0.7 tons.

From this Table it is noteworthy that only V52 produced a satisfactory average yield.

Twelve varieties were tested during the second period 1936-43 and to date eight of these have been discarded, while the remaining "good" varieties are at present in cultivation at the College Farm. The average yields of these varieties are shown in Table II.

Table II

Average Yield of "Good" Varieties of Sweet Potato for 1936-43

Variety	Av. yield of tubers in tons per acre	No. of years tested
B20 ...	4.59	4
V52 ...	3.84	4
SR 281 ...	3.74	4
B34 ...	3.32	2
Black Rock	2.48	4
Magie Murdock	1.15	1

Significant difference at 5 per cent. point=0.7 tons

It will be seen that the average yields of the present varieties are still low although it is possible that yields considerably above the average may be obtained in more favourable years. The best season during the later experimental trials was that of 1940-41, when, however, yields of tubers were only approximately one ton per acre above the annual average for each variety.

(ii) DETERMINATION OF MATURITY AND EFFECT OF TIME OF HARVESTING ON YIELD OF TUBERS

A knowledge of the length of time required for a variety to reach maturity is important both to the research worker and to the farmer; to the former in adjusting the experimental technique to accommodate varietal differences in length of time taken to mature and to the latter in avoiding losses due to premature or late harvesting. The cessation of vine production, followed by leaf-fall and general wilting, is normally taken as an index of maturity of sweet potato crops in Trinidad. Such symptoms are indefinite and may be produced by insect and fungal pests or by a low soil moisture content during short spells of drought. The sweet potato may be said to be mature when it has produced the maximum yield of tubers attainable under the prevailing environmental conditions. Delaying harvesting after this stage results in reduced yields because the tubers not only lose weight by evaporation and respiration but are also exposed to fungal and insect attacks.

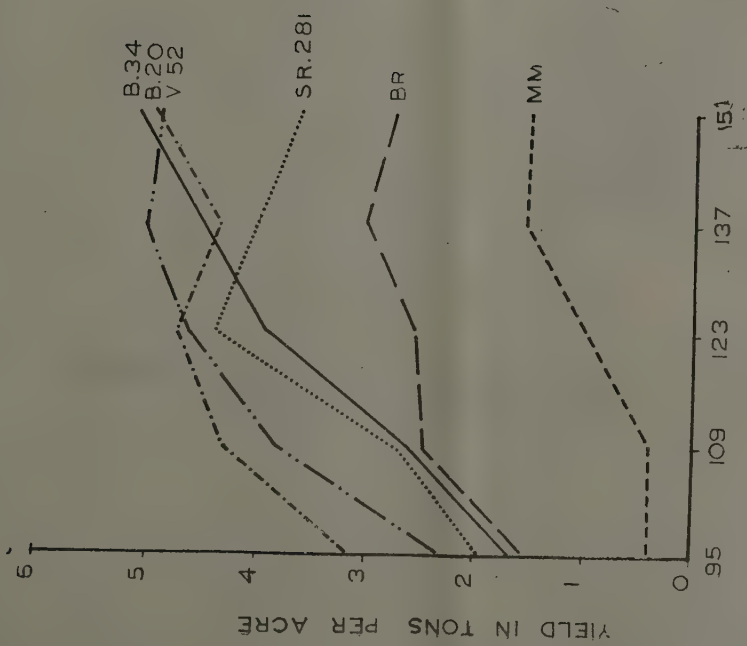
In 1942-43, tests to ascertain the age of maturity of six varieties were performed; these tests consisted of records at fortnightly intervals of the weights of saleable tubers taken from ten plants of each variety. These plants were selected at random from two plots, and sampling was begun three months after planting. The dry matter content of the freshly dug samples was also estimated. The results are shown in Graphs I and II.

If the view is accepted that maturity is attained when the crop has produced its maximum yield of tubers, Graph I indicates that there is considerable variation in the time required for the different varieties to reach this condition. S.R. 281, B 20, and V52 mature in 123 to 137 days, Black Rock and Magie Murdock in 137 days, while B34 takes 151 days or more.

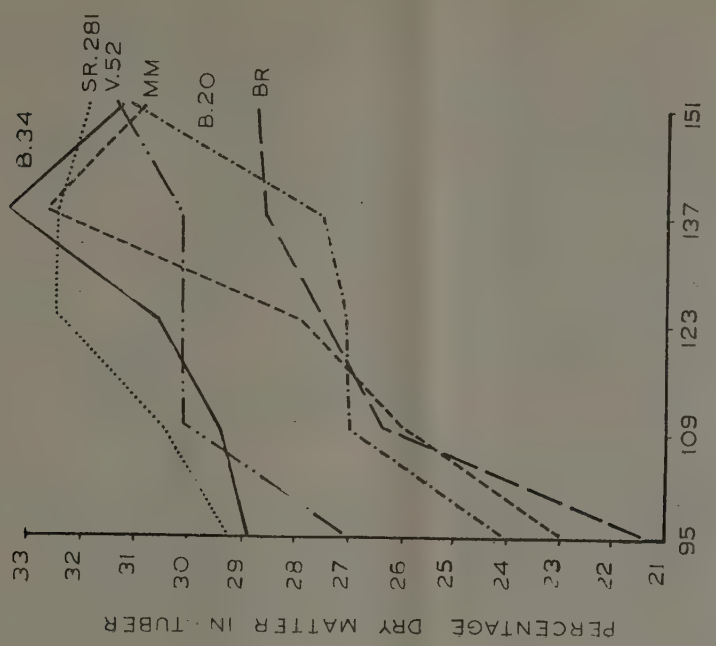
Graph II shows that there are great differences in the dry matter content of the varieties at any one sampling date. The dry matter content of SR 281, B 20, BR, and V52 respectively tended to remain constant for a period at about the time when their respective maximum yields were obtained. The later maturing varieties B 34 and Magie Murdock showed no such period of stability in the dry matter content of the tuber. The apparent absence of such a period might have been due to the limited number of samples taken. Moreover, the sudden decrease in dry matter after the maximum had been reached in the case of these varieties was concurrent with a period of drought which rapidly killed the foliage; thus the consequent cessation of transpiration possibly caused an accumulation of water in the tubers and hence may account for the sudden decrease in dry matter content.

If stability in the dry matter graph indicates maturity then Table III is of interest as it shows a definite relationship between the dry matter determinations and the degree of maturity. The table also explains the part played by the maturity factor in determining yields at the time of harvesting the 1942-43 trial.

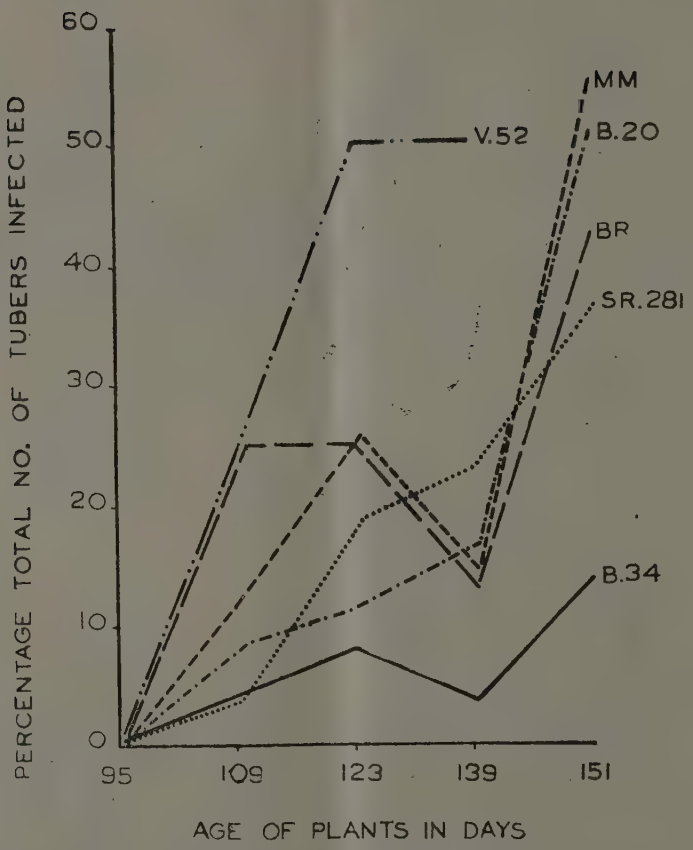
If the experiment had been harvested at 151 days the yields results might have been greater, though still not strictly comparable (*see* Graphs I and II), since all varieties would then have attained maturity. According to Graph II, B34 would have been the heaviest yielder at that time, but, of course, B20, V52 and SR 281 would have lost weight owing to the evaporation of water from the mature tubers.



Graph I. Table tuber yields of 6 varieties during growth 1942-43



Graph II. The accumulation of dry matter in the tuber during growth 1942-43



Graph III. Infection of tubers by larvae of Megastes during growth of crop 1942-43

Table III

Yield of Sweet Potato Tubers in Relation to Maturity at Harvesting 1942-43 Trial

Variety	Degree of maturity as concluded from dry matter graph	Ranking position for yield at time of harvesting experiment (117 days after planting)	Yield obtained at 117 days after planting as shown by yield graph
V52 ... B20	mature	very good	maximum
SR 281...	nearly mature	good	nearly maximum
BR ...		fair	80% of maximum
B34 ...	immature	good	70%
M.M.		very poor	45%

(iii) EFFECT OF MANURES ON YIELDS

Swynerton (9) in 1933-34 tested the effect of dressings of 0, 2, 8, and 16 tons of pen manure per acre, with and without the addition of a mixture of 1 cwt. nicifos and 1 cwt. muriate of potash per acre. Although the season at the time of the experiment was dry, he found that two tons of pen manure increased the total yield of tubers by 60.5 per cent. (over the control) and that of table tubers by 103.8 per cent. 16 tons of pen manure per acre increased the total yield of tubers by 353.3 per cent. and of table tubers by 473 per cent. The increase in total yield of tubers due to the addition of artificial manures was 21.4 per cent., and for the table tubers 26.4 per cent., as compared with the yields from similar pen manure treatments without artificials.

Tidbury (10) in 1935 compared dressings of 3 cwt. of fish manure and a mixture of 1 cwt. nicifos and 1 cwt. muriate of potash per acre. To both these treatments, additions of 0, 5, and 10 tons of pen manure* per acre were also applied. He found no significant difference between the yields produced by the fish manure and the artificial manure, neither was there any interaction between these treatments and the pen manure applications. The differences between the pen manure treatments were, however, significant. Applications of 5 and 10 tons of pen manure per acre gave increases over the control treatment with no pen manure, while the double dressing of 10 tons of pen manure per acre gave a yield significantly greater than that of the single dressing at 5 tons per acre. Walker (ii) in 1936 tested the relative value of 20 tons of pen manure per acre, 10 tons of pen manure per acre, 831 lb. of mixed fertiliser per acre (constitution: 539.5 lb. blood meal, 118.8 lb. superphosphate, 173 lb. muriate of potash) and no manure (control). All manurial treatments were found to increase the yield over the control but no significant difference existed between the individual manurial treatments. He attributed his results to the high state of fertility of the field.

* Pen manure is a West Indian term for farmyard manure made in cattle pens.

(iv) EFFECT OF SPACING ON YIELDS

Halcrow (4) in 1932-33 found that no difference in yield of tubers was produced by sweet potatoes planted on banks 3 feet and 4 feet wide respectively. He also tested three spacings along 3 feet banks, namely, 8 inches, 12 inches and 24 inches, finding no statistically significant difference in the yields produced by the various spacings used, although the yield of tubers produced by the 8 inches spacing was the greatest, and that of the 24 inches the lowest. As would be expected the percentage of large or 'Jumbo' tubers was greatest for the 24 inches spacing. No difference was found in vine production between the treatments.

(v) EFFECT OF SEASON ON YIELDS

In Trinidad there are two ill defined growing seasons for annual crops. The first which extends from May to August is characterised by very heavy rainfall and generally cloudy and highly humid days. The second season occurs from October to January and is marked by intermittent, moderately heavy rainfall, clear days, and comparatively low humidity. Generally, sweet potatoes grown in the first season, *i.e.*, from May to August, produce considerably lower yields than those grown in the period October to January. Moreover the earlier planted crops of the October to January season give better yields than those planted later, *i.e.* in November or December. The reasons for these yield differences have not yet been shown experimentally, but it is thought that rainfall and photoperiodism exert some effect. It has been observed also that there are considerable differences in varietal yields during the wet season, (May to August). Thus, at the College Farm the variety B20 gives an appreciably higher yield of tubers than any other variety, and is consequently the only variety grown for tubers at that time of the year. In the October to January growing season resistance to drought plays a great part in determining differences between the yields of varieties.

(vi) QUALITY

It will be noticed that in the section on Yield, the term "good varieties" has been consistently used. This term implies those varieties which may be readily marketed for human consumption. During the 16 years of experimentation, several introduced varieties were found to be unsuitable in this respect of marketable quality. These had consequently to be discarded although some produced very good yields, B13—7.56 tons per acre in 1935-36 and B33—7.20 tons per acre in 1940-41 are the two most outstanding examples of varieties discarded on account of inferior quality of tuber. Each year, the edible properties of the varieties cooked by boiling were assessed by a jury of consumers. The order of merit for quality of the present "good varieties" is shown in Table IV.

Table IV

Quality of Good Varieties

Variety	Quality (ranking position)	Remarks
B20 ...	1st ...	texture moderately fine; not sweet
SR 281		texture moderately fine; and sweet
Black Rock ...	...	fine texture; and moderately sweet
Magie Murdock	2nd ...	texture fine; dry; acidic sweet
B34 ...	...	texture soft; sweet
V52	3rd ...	texture soft; not sweet

(vii) STORAGE ABILITY

At harvest time a glut on the sweet potato market, with consequent low prices, is liable to occur and it is profitable therefore, for the farmer to store his crop, if possible, until prices become more favourable. Low storage losses are consequently a most desirable feature in any variety. The greatest losses of tubers during storage are caused by micro-organisms such as the fungus *Rhizopus nigricans*. Appreciable losses are also caused by the conversion of starch to cane and reducing sugars, and by the transformation of the reducing sugars to water and CO_2. For the period under review no elaborate storage investigations were undertaken. Most experiments on storage were essentially estimations of the percentage of marketable tubers recoverable after storing, either in sacks or crates, under normal atmospheric conditions, for periods of one to three months. In these experiments all varieties were harvested on the same date so that they were at different stages of maturity. Over-ripe and immature varieties consequently deteriorated and rotted more readily than mature varieties. Table V shows the percentage recovery by weight of saleable tubers following the storage of the good varieties after harvesting in 1927-36.

It is clear from these figures that the varieties Jackson and Red Nut were unsuitable for storage while Black Rock was outstanding for its excellent storage ability.

Table V

Recovery by Weight of Tubers after Storage in Sacks 1927-36

Variety	% recovery after storage
Black Rock ...	83.3
V52	—
Jackson ...	59.7
Red Nut ...	54.3

Table VI shows the storing capacity of the good varieties for 1936-43.

Table VI

Recovery by Weight of Tubers after Storage in Sacks 1936-43

Variety	% recovery after storage
Black Rock ...	83.2
V52	80.7
SR 281 ...	76.2
B34	74.8
B20	74.6
B33	53.3

It is significant that no new variety has yet surpassed Black Rock in the storage trials. However, with the exception of B33 (discarded on account of its poor quality) the other varieties may all be regarded as good storers.

Storage in the field in clamps has been compared with storage in sacks in a store room and also in small uncovered heaps in a store room. A typical potato clamp for storing tubers was made by removing 6 inches of soil from an area 12 feet long by 4 feet wide. Cane trash was laid at the bottom of this area and tubers placed thereon until a heap $2\frac{1}{2}$ feet high was formed. The heap was then covered with trash, which in turn was covered by 3 inches of soil. A narrow drain was finally dug around the clamp to ensure proper drainage. Storage in sacks in a room has been found best, as is shown by the results of Hindson (5) in 1932 and those of Halcrow (4) in 1933 (Table VII).

Table VII

Method of Storage

FACTORS	CLAMP 1933	CLAMP 1932	BAGS 1933	BAGS 1932	HEAP 1933
Sound tubers (% of original weight)	70	75.8	81	83.3	75.5
Decayed do. do.	18	11.2	5	4.8	2.1
Shrinkage do. do.	12	12.4	14	11.0	23.2
Sprouts do. do. ...	—	.625	—	.89	1.16

Control of Pests

The most important pests of the sweet potato in Trinidad are the sweet potato stem and tuber borer *Megastes grandalis* Guenée (Pyralidae) and the slug *Vaginulus langsdorfi* Férussac.

Minor pests include the Scarabee or Jacob,—*Euscepes postfaciatus* Waterhouse,—the Chrysomelid bettle, *Chirida juttata* Olivier; the sweet potato hawk moth, *Herse cingulata* Fabr. and a weevil *Rhyssomatus* sp. (*novalis* Germ. (?))

The limiting factor in the profitable cultivation of sweet potatoes on the College Farm is the sweet potato stem and tuber borer, *Megastes grandalis* Guenée. This is a South American species and has not penetrated to the Antillean Islands. The eggs are laid on the lamina and petiole of the leaves and are difficult to find. The larvae feed superficially on the leaf to a limited extent, and soon penetrate the stem, usually about an inch above the soil surface. They then tunnel through the stem and often penetrate into the tubers. Pupation occurs in the stem or tuber. The main stem is weakened and readily breaks during cultivation; this may result in the complete loss of the plant. Tubers perforated by the tunnels of the larvae become susceptible to the ravages of scavenging insects and secondary decay-producing fungi and bacteria. Bored tubers are unsaleable for human consumption.

No effective measures of control are practised in Trinidad. It is said that if the crop is planted on the flat and then gradually "moulded" up by throwing soil around the stem so that the plants eventually stand on a small bank, damage by the borer is reduced, but this lacks experimental proof. The writer tested the possibility of control by insecticides. The following were used:—(i) Cryolite spray, (ii) lead arsenate spray, (iii) milk of lime spray, (iv) a lead arsenate-cement bait around the base of the stem, and (v) a repellent band of a tar compound around the base of the stem. Sprays were applied at fortnightly intervals. These tests were not successful, since the Cryolite spray which gave the best results reduced the number of infested plants by only 12.5 per cent. Furthermore, it was thought that control by means of insecticides was not the best approach to the problem since the crop is grown mainly by peasants, many of whom should not be entrusted to use poisonous substances on food crops. Cultural control methods were accordingly sought and it was decided to estimate the part played by early harvesting, in reducing the degree of infestation of the tubers.

Accordingly, in 1942-43 the percentage of tubers of six varieties attacked by *Megastes grandalis* was estimated at fortnightly intervals from 95 to 151 days after planting. The results as shown by Graph III indicate that, irrespective of the variety, the total percentage of tubers infected by larvae increased rapidly from the time the tubers were produced until the date of harvesting. When harvested as soon as the tubers had matured, "early" varieties showed lower percentages of tuber infections than "late" varieties. Thus, for example, mature tubers of B20 harvested from 109 to 123 days after planting were less damaged than those of Magie Murdock harvested after 151 days. But when B20 was permitted to remain in the soil for 151 days, the amount of damage to that variety was as great as for Magic Murdock. The use of 'early' varieties together with early harvesting is therefore a means of economically reducing losses caused by the pest.

Table VIII drawn up from the results clearly illustrates this point.

The practice of storing tubers in the soil by deferring harvesting is therefore not recommended.

B34 gave consistently low percentages of tuber infection. This is, however, not due to true resistance but to the production of relatively more tubers at deep levels in the soil, where they are less liable to attack by the borer.

The slug *Vaginulus langsdorfi* Férussac is capable of destroying plants and greatly reducing yields during periods of high infestation, by feeding on the stem and leaves. An effective method of control, recently tested by the Department of Entomology, involves the use of a bait of metaldehyde (1).

Miscellaneous Investigations

(i) VINE PRODUCTION

Observations on vine production and varietal resistance to drought were made. These have been listed as miscellaneous investigations as

Table VIII

Per cent. of Saleable Tubers Damaged by Larvae of Megastes grandalis

Variety	117 days after planting	151 days after planting
V52	39.5 (tubers nearly mature)	32 (tubers over mature)
Black Rock	25.0 (tubers immature)	42 (tubers mature)
Magie Murdock	20.0 (tubers immature)	55 (tubers mature)
SR 281	11.5 (tubers nearly mature	36.5 (tubers over mature)
B20	9.8 (tubers mature)	53 (tubers over mature)
B34	6.5 (tubers immature)	13.8 (tubers mature)

they were sporadic rather than consistent annual features of the investigations. A vigorous and abundant growth of foliage not only ensures an effective cover of weeds and soil but is an essential prerequisite for a good yield. The results are shown in Table IX.

Table IX

Varietal Vine Producing and Drought Resisting Properties Period 1936-43

Variety	Factors	
	Vine production	Resistance to drought
B33 ...	poor	resistant
B20 ...	good	moderately resistant
V52 ...	fair	susceptible
SR 281 ...	fair	susceptible
B34 ..	good	moderately resistant
Black Rock	poor	resistant

(ii) STORAGE OF CUTTINGS BEFORE PLANTING

Inniss (7) and Walker (11) in 1935 found that there was no loss in viability of cuttings which were stored in bags for a week, though after longer periods the material deteriorated rapidly. Inniss (7), continuing these studies in 1937, showed that there was no difference in viability between cuttings stored in soaked sacks and those stored in dry sacks. There was, however, a big difference between cuttings, with leaves left on and those with the leaves removed. After a week of storage in sacks, cuttings with the leaves attached were in a bad state, the leaves being reduced to a slimy mass and, the stems showing signs of rot. Cuttings with leaves removed remained in good condition. The percentage take of cuttings with leaves removed was appreciably greater than that of those with the leaves left on; moreover, the former produced new growth more quickly. It was also found that cuttings taken from the basal portion of the vine stored better than those from the top.

Discussion

The annual varietal experiments from 1927-43 gave considerable information about yields. When varieties having different growth periods were tested, planting and harvesting of all varieties were performed on the same dates. The yield of tubers obtained was consequently influenced by relative degrees of maturity of the different varieties for the age of maturity tests made in 1942-43 showed how seriously simultaneous planting and harvesting must have affected the experimental results. This difficulty could best be obviated by first determining the age of maturity of all varieties and classifying them into separate groups, each group containing varieties which reach maturity at the same age. The varieties within each group should then be tested against each other only. Regular weekly or fortnightly determinations of the dry matter content of the tuber from the time of its production will provide an indication of the development of maturity. Maturity, which is regarded as the stage at which the maximum possible yield is produced, is indicated by the dry matter content of the tuber remaining constant for a significant period. After this stage, the dry matter content may either fall rapidly owing to the death of the foliage, or rise owing to excessive loss of water from the tuber by evaporation.

Harvesting at maturity is essential for accurate results in storage and cooking tests as in yield trials. There is a great need for more information on the cooking and storage quality of varieties. The cooking quality of the tuber at various ages and the response of different varieties to different methods of cooking are interesting lines of investigation. The reaction of varieties to various conditions and methods of storage is also worthy of further research.

The practice of allowing tubers to remain in the soil after maturity has been reached is bad, because it exposes the tubers to increased infestation by *Megastes grandalis* Guenée. Early varieties show a lower percentage of infected tubers than late varieties at maturity. This superiority is, however, completely lost if harvesting of the early varieties is deferred. Varieties which produce a large number of deep rooted tubers show less percentage tuber infection per plant than varieties (with a similar maturation period) of which the tubers are more shallow rooted or less numerous. The ideal variety for use in areas where *Megastes grandalis* Guenée is prevalent is one which produces heavy yields, matures in four months and has a large number of deep rooted tubers.

Acknowledgments

Grateful acknowledgment is made to the Principal and the Professor of Agriculture, Imperial College of Tropical Agriculture, for permission to complete and publish this paper summarising the results of the various field and variety trials and other investigations with the sweet potato carried out between 1927 and 1943 by successive years of diploma and post-graduate students under the aegis of the College Department of Agriculture. It is only in the last three years in his capacity as a member of the staff of the Department that the writer has taken any major share in the planning and direction of the actual experiments in the field. To the large number of past and present students from whose reports and experimental records, most of the data and information embodied in this paper have been derived, I wish to express my deep indebtedness and thanks.

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Appendix

List of Sweet Potato Varieties tested at I.C.T.A. Farm

1927-36	1936-43
White Jackson	B33
Joe Mendes	B20
Turkey Claws	SR 281
White hen and chicken	B32
Prince William	B44
Black Sam	B64
Jackson	B26
White Sam	B62
Black Vine	B29
Pumpkin steward	B52
Sealy	B34
Hen and Chicken	Magie Murdock
Black Rock	
Red Nut	
Purple vine	
Yellow New Jersey	
B1	
B2	
B5	
B6	
B13	
V52	

CRUMB STRUCTURE *

All soil research aims, ultimately, at the production of larger and better crops for the better nutrition of our human and animal population. It is, therefore, natural that early efforts were directed towards assessing the fertility of soils through a study of their chemical composition and the availability of plant foods contained in them. The limitations of such methods were soon felt when it was experienced that soils having an adequate mineral content can yet be infertile and that soils apparently similar in regard to their chemical composition and mechanical analysis can show wide differences in yielding capacity. It was then that the importance of air and water for crop growth was adequately realised. Great strides have since been made in our knowledge concerning the physical properties of the colloidal material in the soil. But we have not, as yet, evolved a satisfactory method for giving quantitative characterization to the physical condition of the soil, especially in its natural field state. It may, nevertheless, be stated that so many aspects of soil physics, particularly those having a bearing on some relation between soil air and soil water, are intimately connected with the field structure of soils that studies on the degree of aggregation and the stability of aggregates have contributed largely to a fuller understanding of the processes controlling soil fertility. This emphasis on the structure of soils as a vital factor in their evolution or degradation is, undoubtedly, a great improvement on the older view which merely stated that the soil was deficient in this or that nutrient and that something must be done to restore its level or maintain its supply.

Structure Defined

Structure is a term expressing the arrangement of the individual grains and aggregates that make up the soil mass. The individual grains are the mechanical or textural separates such as sand, silt and clay and are, therefore, the primary soil particles while the aggregates consist of an intimate grouping of a number of primary particles into a secondary unit. The structure of any particular horizon of a soil profile as it appears to the eye of the soil morphologist may be considered as the macro-structure of the soil in this layer and refers to the natural arrangement of the soil when in place and undisturbed. Based on the size, shape and character of the faces and edges of these aggregates, terms such as 'nutty', 'mealy', 'granular', 'prismatic', 'columnar', 'platy', 'honey-comb', etc., are used to distinguish between the principal types of field structure. Another classification of structure takes into account the structural arrangement of the primary and secondary particles, both in themselves and in a mixture of the two. Several other structural groupings have been suggested such as those based on the type of pore space and the nature of the

*Extract from an article on "Crumb Structure and Soil Fertility" by V. A. Tamhave and A. Sreenivasan of the Institute of Plant Industry, Indore, which was published in *Current Science*, Vol. 12, No. 5, 1943. The part of the article dealing mainly with crumb structure is reproduced here as it represents a very useful survey of present day knowledge on the subject. All references have been omitted.—*Ed.*

binding material that is responsible for aggregate formation. Agriculturally, however, the kind of structure that is important in its effects, both direct and indirect, upon the soil as a plant habitat is the degree of aggregate formation which resists, under ordinary conditions, the dispersing action of water or beating rain. Aggregation of soil particles into crumbs or granules is the only structure having any practical value and the only one the formation of which has been studied in any detail.

Tilth of Soils

By tilth, we understand, ordinarily, the pulverulent condition of the soil which results from successful tillage. A good tilth is a condition which the farmer tries to produce and maintain, when produced, so that it is most suited to the growth of plants. This condition can be recognized in the field by an experienced farmer. Unfortunately, there is, as yet, no single method by which it can be measured quantitatively, for it is the result of many factors which have not been isolated and analysed, but one of the fundamental factors is undoubtedly a good crumb structure. Tilth is closely related to this structure or aggregate formation since both are associated with the presence of colloidal material. Soils devoid of colloids have what is known as single-grain structure, each grain acting as a unit and no compound particles being present. Because of the size of the grains, the tilth or sandy soils is seldom bad. They are well drained, but of course lack the capacity to store moisture or retain plant foods, especially in tropical tracts. Soils containing varying amounts of colloids, on the other hand present a rather serious problem. The individual grains are so small that if they are forced into a position of close packing, either by mechanical pressure or by the beating action of rain, they become exceedingly hard and impermeable to both air and water. Hence, soils containing appreciable amounts of colloids and with single-grain structure, are the most difficult to manage. Soil husbandry should, therefore, aim at the building up of stable aggregates of crumbs from these single grains.

Structure and Air-Water Relations

For healthy plant growth, the plants must have a continuous supply of soil moisture which does not reach the two extremes of drought and waterlogging. For this condition, two properties of the soil are of great importance: (*a*) the ease with which excess of water can drain away from a soil under gravity, and (*b*) the amount of water the soil can hold against gravity. These needs are satisfied by the soil having a suitable distribution of pores. If all the pores are large, as in coarse sand, water will drain away freely and air will have easy access to all parts, but if the pores are small, as in silt or unflocculated clays, water will be held in them against gravity and air will enter with great difficulty and the plant will die of asphyxiation. The ideal soil has such a pore size distribution that there are sufficient large pores or macro-pores for adequate gaseous exchange to take place between the soil air and the atmosphere and sufficient small pores or micro-pores for the soil to hold a reasonable amount of water against drainage for the utilization of plants. This ideal condition of the soil is in part dependent upon the size and arrangement of the soil particles and is mainly controlled by crumb or aggregate structure. In an aggregated soil, the pore space is discontinuous, for the fine pores inside the individual aggregates are usually much finer than those between the aggregates. These pockets of fine pores inside each aggregate act as water reservoirs surrounded by large channels down which surplus water can drain away and so facilitate gaseous exchange between the soil air and the atmosphere.

Flocculation vs. Aggregation

Since structure is associated with the colloidal fraction of the soil and since compound particle formation of colloidal materials is usually referred, to as flocculation, early students have attempted to approach the problem of soil structure or formation of soil granules by a study of the flocculation of clay soils. While, however, there are instances where mere flocculation of puddled soils have been followed by increased productivity, there is a vast difference between flocculation from the purely colloidal point of view and aggregation from the standpoint of structure. Chiefly, a floccule is stable only as long as the flocculating agent is present whereas stable aggregates are held together by a cementation of the flocculated particles. It is possible that flocculation is an essential first step in the granulation process but there is no doubt that granulation is much more than flocculation, involving as it does a combination of different factors.

Hypothesis of Crumb Formation

The mechanism of the formation of the soil aggregates is one of the most important but hitherto least understood phases of the soil structure problem. The cause of granulation has been variously attributed to the water film, the exchangeable cations, the organic matter, the inorganic colloids of the soil, as also the natural processes of heating and wetting. But, it would appear that the cementation of clay particles at low moisture contents is probably the most important mechanism enabling mineral soils to form crumbs.

Crumb and Clod Structure

The difference between the crumb structure and clod structure of a soil is not yet understood, nor has it yet been possible to distinguish them on purely quantitative grounds. It has been assumed that clod structure is produced by purely mechanical means such as cultivation and can be altered at will by such means whereas crumb structure is an inherent property of the soil displayed when conditions are suitable.

By ploughing and cultivating a clay soil when wet, huge clods can easily be produced. If these clods are now subjected to a hard frost after the thaw, the clods will have fallen down to small, very stable crumbs so that the land will have lost its clod structure and gained a crumb structure through the agency of the frost. If, on the other hand, these wet clods are dried, they will form hard lumps very resistant to cultivation. So far, the distinction between clod and crumb structure is clear. But if these clods are rewetted under suitable conditions and then carefully cultivated, they will fall down to smaller aggregates and, by continued suitable wetting, drying and cultivation, aggregates of any size can be produced. These aggregates can only be formed by the agency of wetting and drying, cultivation merely hastening the breakdown into suitable aggregates. Again, if the soil were originally ploughed under appropriate conditions, it would break into quite definite aggregates as it was turned in the furrow. This example shows that it is rather difficult to distinguish strictly between crumbs and clods.

The Stablity of Structure

Crumbs may have two types of instability: (1) mechanically weak, and (2) unstable in water. If the soil clod does not contain sufficient colloidal material, the crumbs or clods formed in the soil will be mechanically weak and break down very easily to dust by cultivation operations, by the erosive action of the wind or by mechanical shattering through the action of falling rain drops. The last effect is well illustrated by the capping which heavy rain causes on some types of soils. Water-instability of crumbs is in part due to physico-chemical causes. Thus, if the clay forming the crumbs contains much replaceable sodium, the crumbs will be mechanically strong when dry, but will disintegrate when wetted with water, due to the weakening of the cohesion between the individual clay particles forming the crumb. This type of instability often occurs in arid regions, particularly when subjected to irrigation and has caused grave agricultural damage to large tracts of irrigated land.

The water-stability of the aggregates is of the utmost importance in promoting and preserving good structural conditions in the soil. Water may cause a breakdown or deterioration of the aggregates through the process of swelling and 'exploding' of the entrapped air (referred to later), or by mechanical action as with beating rain. The impact of falling rain will have a dispersing action on the aggregation of an exposed soil. These dispersed particles will then be carried into the soil pores causing compaction.

Aggregate Analysis

Aggregate analysis of the soil measures the relative distribution of the various sizes of aggregates and permits a calculation of the percentage aggregation of the finer mechanical separates. Such an expression is really an index of structure though, of course, it does not characterize the type of structure. A large number of methods of aggregate analysis have been proposed and used. In general, three techniques are employed to accomplish such an analysis. They are: wet and dry sieving, elutriation and sedimentation. Russell and Tamhane have recently reviewed the different methods and their limitations. According to them, the aggregate analysis of the soil should be carried out under two conditions of wetting: (1) a slow wetting of the air-dry soil, when the minimum break-up of the larger aggregates takes place and which may represent the inherent water-stable aggregation of the soil, and (2) a rapid wetting of the air-dry soil, which causes a maximum break-up of the larger aggregates and may give the absolute water-stable aggregates. It would, however, appear essential that for obtaining a true picture of the structural capacity of field soils, the samples should not be completely dried or stored for long before making an aggregate analysis.

In the expression of results, the percentage of aggregates greater than 0.05 mm. in diameter has been used to characterize the "state of aggregation" of the soil. This lower limit has been chosen on the basis of the fact that the curves for the aggregate and mechanical analyses intercept near this point, which makes it possible to determine aggregates smaller than 0.05 mm. from the two curves.

VITAMIN C INDUSTRY

The actual commercial development of the synthetic production of vitamins was initiated by a chance procedure that had apparently little connection with the vitamin industry as we know it today. By a chain of fortuitous events, it had become possible to synthesize the hitherto rare ascorbic acid from glucose by a simple set of chemical and biochemical reactions and, in 1934, to introduce synthetic vitamin C commercially. A gradual realization that the increasing commercial demand for this material could be supplied by a synthetic material made from glucose gradually led to a fresh concept of the nature of the vitamins. It began to be apparent that, after all, the vitamins might turn out to be substances capable of economic synthetic commercial production—a probability that has become an astonishing reality. The early commercial supply of vitamin C was little more than a scientific novelty and was sold to the trade in ounces. Its use in the beverage and related food industries gradually increased, so that today, under General Preference Order M-269, the sale of vitamin C in the United States is governed by priority ruling to control the estimated production of 6,000,000 lb., a figure that may reach 8,000,000 in 1944, a decade after its introduction.—(C. R. Addinall, *Merck & Co., Inc., Rahway, New Jersey*; *Journ. Chem. Education*, 1944, Vol. XXI, No. 1, January, p. 49.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Nature of Vitamin B

The vitamin theory of Funk had postulated the existence of various deficiency diseases, including rickets, scurvy, beriberi, and pellagra. Previous to 1920, the antiberiberi vitamin factor had been relegated to the water-soluble B factor of McCollum and Davis and, consequently, designated as vitamin B. The work of Smith and Hendrick in 1926 showed the presence of both growth and antiberiberi factors in the so-called vitamin B extracts. Thus, when Goldberger further demonstrated that these extracts from liver, yeast, and other food sources also contained an antipellagra factor, confusion resulted, and it was not until recently that the tangles of the so-called vitamin B complex have been straightened out. The confusion has been cleared up, due mainly to work in related fields on growth factors and to broader concepts of the biological function of the vitamins. The many investigations of the growth-stimulating factors contained in sterile decoctions of yeast, termed "bois" by Wildiers in 1901, have led to the recognition of vitamin B1, B6, biotin, pantothenic acid and inositol as well-established members of the group. Growth factors for other micro-organisms include, in addition to those named, vitamin B2, nicotinic acid, folic acid, p-aminobenzoic acid, and choline—all of which occur in vitamin B extracts. It seems probable, therefore, that all these compounds, which are growth factors for micro-organisms, may function as vitamins for animals, and that they all play a vitally important part in life processes. Many of these compounds were previously well-known chemical entities. The use of their long-established names and the adoption of other names, such as thiamin, to replace previous nomenclature with therapeutic indication, is rapidly rendering obsolete the terminology vitamin B1, B2, B6, &c.—(C. R. Addinall, *Merck* & Co., *Inc., Rahway, New Jersey; Journ. Chem. Education*, 1944, Vol. XXI, No. 1, January, p. 49).

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Human Vitamin and Mineral Requirements per Individual per Day

Calories	....2,800 for energy.
Protein	....66 g. for tissue building.
Calcium	....900 mg. (98 g.=1 oz.).
Iron	....12 mg. blood making
Vitamin A	....4,700 Intern. Units (eyes, skin, body linings).
Vitamin B1 (=Thiamin)	....1.6 mg. (nerves, assimilation of sugar and starch).
Vitamin B2 (Riboflavin)	....2.3 mg. (oxygen usage by cells).
Niacin	....16 mg. (nutrient, preventing pellagra).
Vitamin C (Ascorbic acid)	70 mg. (keeps body cells together).

—(*J. Chem. Education*; Jan., 1944, p. 28).

Terracing for Soil and Water Conservation

U.S.D.A. *Farmers' Bul.* 1789 brings up to date information on methods of terrace construction and maintenance. Special consideration is given to the place of terracing in the general erosion-control programme. The results of investigations of soil and water losses from terraces on different soil types at the soil and water conservation experiment stations are considered in relation to the terracing programme. Methods of construction of the different types of terraces are well illustrated.

* * *

Cardboard from Coconut Fibre

A new enterprise for manufacturing cardboard from coconut fibre in Ceylon has, it is reported, proved highly successful. The scheme was developed by Mr. S. R. K. Menon, an Indian Chemist, with the financial assistance of the Coconut Board of Ceylon. After certain preliminary experiments, a pilot plant was established in Colombo and it is now able to turn out cardboard of high quality with a polished surface. Proposals for manufacturing the material on a commercial scale are likely to be considered shortly by the Coconut Board. The new product is called 'Coconite'.—(*Current Science*, Vol. XII, No. 6.)

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Production and Fertilizer Use of Urea

The production, properties, and non-fertilizer and fertilizer uses of such urea fertilizer materials as Uramon, urea, urea-ammonia liquors, and Calurea are considered in the first part of Circ. 679 of the U.S.D.A. The second part of the circular presents a discussion of factors involved in the use of urea fertilizer materials in crop production and includes leachability, availability, effect on soil reaction, proper use, effect on quality of crops, use in mixed fertilizers, and certain special uses, such as for composting and as a component of starter solutions.

* * *

Relation of Magnesium Deficiency in Grapefruit Leaves to Yield and Chemical Composition of Fruit

According to the Florida Agr. Expt. Stat. Bull. No. 331, seedy grapefruit contains more nitrogen and minerals than do "seedless" varieties. Crop production causes a reduction in nitrogen, phosphate, calcium, magnesium, and manganese of the leaves near the fruit. This effect is more pronounced in seedy than in seedless varieties. Bronzing of foliage occurred only in seedy fruit trees and was associated with a deficit of magnesium in the bronzed leaves. Leaves of seedless varieties were not bronzed as the foliage is abundant and the loss of magnesium from the leaves is not great. Heavy crops of seedy fruit cause partial defoliation and dying-back of branches due to poor supply of available magnesium.